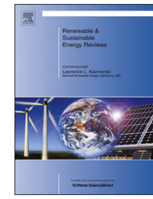
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An overview on global warming in Southeast Asia: CO_2 emission status, efforts done, and barriers

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ABSTRACT

Southeast Asia is one of the most vulnerable regions to the global warming threats. Although it is not the main global carbon dioxide (CO_2) producer, its emission will become significant if there is no action taken. CO_2 sources of Southeast Asia are mainly contributed by electricity and heat production, as well as transportation sector. The efforts taken by these countries can be categorized into governmental and regional level. This review article is giving an overall picture of global warming issue in Southeast Asia. We will review on the efforts that have been done in Southeast Asia region to address global warming issue. ASEAN has an important role to play at regional level to tie its entire member countries into cooperation, creating a borderless regional cooperation in this issue. The article will also look into some shortcomings that faced by these countries. With the purpose to gain attentions from all parties into the seriousness of global warming issue in Southeast Asia, we hope that more efficient measures can be taken and this region, too, can successfully achieve their CO_2 reduction target as promised.

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1. Introduction

Global warming issue is at its alarming level worldwide nowadays. Southeast Asia, which consists of Brunei, Myanmar, Cambodia, Indonesia, Laos, Malaysia, Philippines, Singapore, Thailand, and Vietnam, is one of the vulnerable regions to global warming that should not be overlooked [1]. Lightning floods, droughts, landslides, tropical cyclones are some of the instant adverse impacts attacked the region recently that affect the countries' politic and economic, public health and life quality. Indian Ocean Tsunami 2004 will never be forgotten by all the region residents. Southern Leyte Mudslide 2006 buried over 1100 lives in the Philippines [2] while Bopha typhoon that attacked Mindanao, Philippines in December 2012 affected more than 213,000 people in the country [3]. Besides than logging activities, heavy rainfall was believed to be the key factor that brought to landslides in the nation [4]. Besides that, Southeast Asia is expected to be affected by the sea level increment about 3–16 cm by 2030 and 7–50 cm by 2070 [5].

Southeast Asia countries are considered as a small contributor to the world's carbon dioxide (CO_2) emission. In 2006, total emission of these ten countries was merely 1045.95 million tons (MT), which was relatively low compared to the two giant CO_2 emission countries, China (6103.49 MT) and United States (5975.10 MT) [6]. However, their CO_2 emissions should not be disregarded because these countries recorded an increasing trend in CO_2 emissions throughout the years as shown in Fig. 1. Asia-Pacific Energy Research Center (APERC) predicted a quadruple CO_2 emission in Southeast Asia by 2030 if there is no action taken or change in policies related to this issue [1] and if this happen, it is expected that the emission values will become more significant compared to United States' and China's.

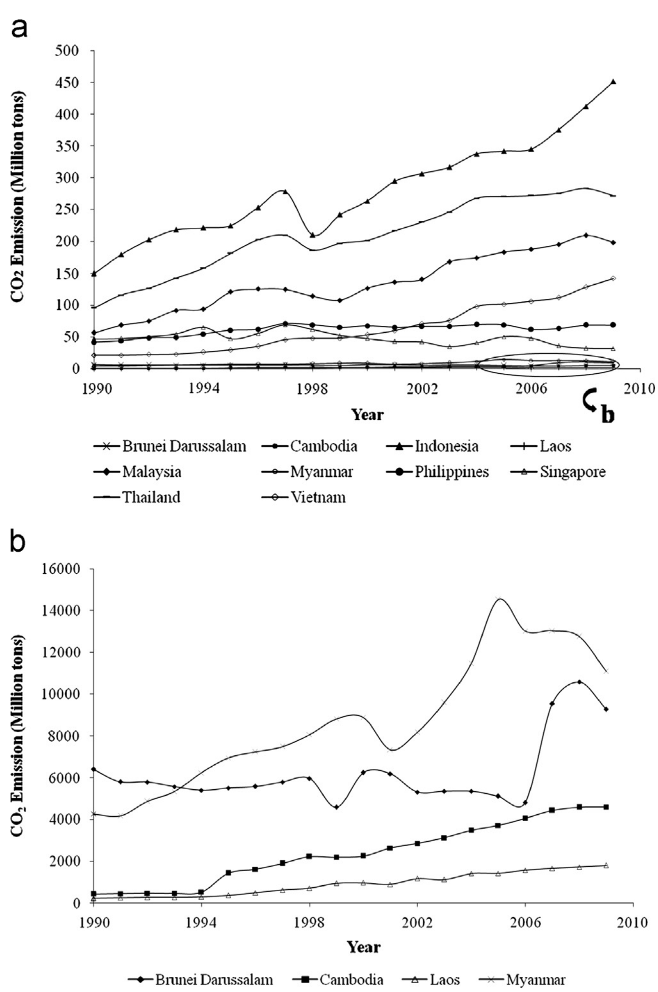


Fig. 1. CO_2 emissions in Southeast Asia countries 1990–2009 [77,78].

Maintaining or reducing CO_2 emission along with sustainable development has become a tough task for most Southeast Asia countries. However, the country governments have shown their concerns and enthusiasms in this issue. All these countries have signed and ratified Kyoto Protocol, entitled under non-Annex I parties [7]. Most of these countries, too, associated themselves positively in weakly-bound Copenhagen Accord [8]. Numerous conferences and bodies have been formed under these countries as well as ASEAN, oriented to reaching a consensus in mitigating CO_2 emission and global warming effects. We will further discuss about these efforts done in the latter section.

Since the commencement of Kyoto Protocol, developed countries, such as European countries and Japan, have strived to reduce their nations' CO_2 emission, and visible results have been observed. Table 1 shows the changes of CO_2 emission in term of tons per capita of these countries compared to Southeast Asia countries. It is worth to notice that some of the countries, including Brunei, Singapore, Indonesia, Malaysia, and Thailand, have comparable CO_2 emission value with developed countries. The drastic increment of the CO_2 emission was related to the flourishing industrial development in the countries, such as Indonesia, Malaysia, Thailand and Vietnam. In addition, there is a misconception that CO_2 emission from Southeast Asia is less significant compared to the major emitters, United States and China. Indonesia, with the fourth highest population in the world,

Table 1
CO_2 emission per capita and CO_2 emission change (compared to 1990) in 2009 [77,78].

Region	Country	CO_2 emission (tons per capita) 1990	CO_2 emission (tons per capita) 2009	Variation (%)
Southeast Asia	Cambodia	0.05	0.33	560.0
	Brunei	25.47	23.69	−7.0
	Indonesia	0.81	1.90	134.6
	Laos	0.06	0.30	400.0
	Malaysia	3.11	7.10	128.3
	Myanmar	0.11	0.23	109.1
	Philippines	0.68	0.75	10.3
	Singapore	15.41	6.39	−58.5
	Thailand	1.68	3.95	135.1
	Vietnam	0.32	1.65	415.6
Europe	Germany	12.03	8.97	−25.4
	France	6.85	5.61	−18.1
	Netherlands	10.98	10.26	−6.6
	Spain	5.63	6.28	11.5
	Sweden	5.97	4.70	−21.3
	United Kingdom	9.96	7.68	−22.9
East Asia	Japan	8.86	8.63	−2.6

contributed 4.73% of total world greenhouse gases emission [8]. It is a demand of immediate attention to the CO_2 emission in this region. The biggest challenge and burden faced by Southeast Asia countries now is to find a resolution to keep the development and global warming mitigation in balance.

This article reviews on the current condition of CO_2 emission and global warming in Southeast Asia. CO_2 emission sources in these countries that contribute to the increasing trend, as reported previously, will be discussed. In conjunction with that, we will look into the governmental and regional efforts done to mitigate global warming in term of CO_2 reduction, as well as deficiencies of their implementation, followed by comments and recommendations. It aims to gain attentions of its readers to envisage the seriousness of global warming in this region and bring in more efforts and cooperation to mitigate the problem.

2. CO_2 sources in Southeast Asia

CO_2, together with methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulfur hexafluoride (SF_6) have been listed in Kyoto Protocol 1998 as greenhouse gases (GHGs) that contribute to global warming [9]. CO_2 gives greatest impact on global warming due to its relatively high emission to the atmosphere compared to other GHGs [10]. The main contributors of CO_2 in Southeast Asia are from power generation and heat production, manufacturing and construction, transportation etc.

Fig. 2 shows percentage of CO_2 emissions by sectors in some of the Southeast Asia countries in year 2001. Electricity and heat production sector is the major CO_2 emission sources in these developing Southeast Asia countries. It is also the most important CO_2 emission sources worldwide, delivering 26% of the total global CO_2 emission [11]. In power plants, CO_2 is produced when fuel is combusted in air. In order to reduce this greenhouse gas emission, the approaches done can be generally categorized into three groups, (1) power plant efficiencies increment (2) renewable energies substitution and (3) carbon capture and storage (CCS). Recently, integrated gasification combined-cycle (IGCC) power plants and natural gas combined-cycle (NGCC) power plants are two of the well-developed technologies that upgraded the efficiencies of the electricity generation process. Renewable energies, such as solar energy, wind energy and hydro energy have been proposed as alternatives for energy production [12]. Meanwhile, CCS is a concept where CO_2 is captured from the emission point,

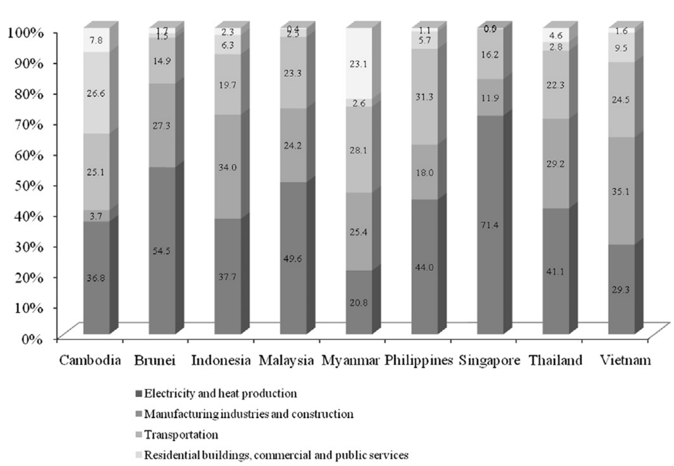


Fig. 2. Percentage of CO_2 emissions by sectors in some of the Southeast Asia countries 2008 [15].

transported and stored in ocean or geological reservoirs [13]. At the current stage, new-designed technologies and renewable energy are still at a preliminary stage to replace the traditional power plants. Fossil fuel will still remain as the most imperative energy source due to its wide availability and economical viability [14].

Transportation is another influential sector in CO_2 emission. CO_2 from vehicles is produced from engine combustion and catalytic converters, which convert harmful carbon monoxide (CO) from incomplete combustion to CO_2. Southeast Asia countries endured with drastic increase in number of vehicles every year. Rapid development of public transport industry, too, contributed to the increment in CO_2 emission. In countries like Indonesia, Thailand, and Vietnam, transportation sector contributed the significant CO_2 emission [15]. Improper planning of transportation system, utilization of low quality petrol are some of the additional factors that will worsen the condition. In a short-term, fuel efficiency enhancement; smart drivers training will be the most straightforward methods to reduce the emission. However, the ultimate solution will be finding a replacement of these fuel-consuming vehicles with environmental friendly vehicles. Recently, various types of environmental friendly vehicle technologies have been developed. Fuel cell (FC)-power vehicles and hybrid vehicles are among the two advanced technologies that going to replace the current fuel-consuming vehicles [16]. Hybrid vehicles are vehicles with combination of two or more power sources. Electric-gas hybrid vehicle, which has a combination of internal combustion engine (ICE) and small electric motor, starts to gain attention among vehicle users nowadays [17]. Meanwhile, commercialization of FC-power vehicles still needs more research and investments.

Manufacturing, agricultural, and residential activities are among the main secondary factors which contribute to the CO_2 emission in Southeast Asia countries. Their CO_2 emissions are relatively lower than power plants and transportation sectors but significant. CO_2 emissions from manufacturing sector are mainly contributed by chemical, petrochemical, iron and steel, cement, paper and pulp, and other minerals and metals industries [18]. In the manufacturing industry for example in cement industry, when limestone ($CaCO_3$) is converted to lime (CaO) [19], CO_2 was produced from the fossil fuel combustion in the production process or reactions in the midst of the production.

Whereas, in agricultural sector, besides the fossil fuel combustion in engines utilization, deforestation is the major factor that increases the CO_2 emission. Southeast Asia countries inherited abundant tropical rain forest, which acts as big pool for CO_2 sink that stores at least 42,000 million metric tons (Mt) of soil carbon [20]. Clearance of the natural heritage in the name of development has caused the release of CO_2 and disproportion in the natural CO_2 balance cycle. CO_2 from residential sector mostly comes from daily habits of the residents, such as electricity consumption, use of detergents in daily washes, open-burning activity etc.

It is worth to note that regardless the emission sources, CO_2 release is commonly caused by fuel combustion and outflow of the CO_2 sink pools. Besides that direct CO_2 capture from emission point, most of the efforts have been focused on fuels improvement, including development of alternative fuel and enhancement of fuel efficiency. Enforcement of the CO_2 sink pools conservation is also crucial for this region that with dense tropical forest.

3. Efforts in CO_2 reduction

3.1. Governmental efforts

3.1.1. Energy sector

At present it is noticed that none of the Southeast Asia countries gives penalty to plants or industries with extra CO_2 emission. CO_2 measurements are yet to be sound logical because the industries are

up to date highly relying on fossil fuel combustion. Furthermore, CO_2 capture technologies are found to be uneconomical to be merged into most of the production plants. The one and only CO_2 capture plant so far in Southeast Asia was built under Petronas Fertilizer Co., Malaysia and started its operation in 1999 [21]. It was an output from collaboration with Japanese companies, Kansai Electric Power Company and Mitsubishi Heavy Industries Ltd.

Renewable energy, energy saving and energy efficiency enhancement can reduce CO_2 emission indirectly. All Southeast Asia countries have their country policies and legislations in enhancing energy efficiency as well as promoting renewable energy. Table 2 shows some of the policies and legislations which can bring to CO_2 reduction in some extent. Being enriched with variety natural resources, development of renewable energy is

Table 2
Some of the relevant policies/acts/laws in Southeast Asia countries that will reduce CO_2 emission of the region.

Country	Policies/Acts/Laws	Aims/Objectives	Ref.
Brunei Darussalam	'1 Tree Felled Plant 4' Policy 1993	- To prompt the forest conservation in the nation.	[26]
	Power Development Policy	- To achieve an efficient transmission and distribution system.	[27]
	Brunei Natural Gas Policy 2000	- To utilize natural gas in domestic electricity production.	
Cambodia	Environment Protection and Natural Resource Management Law 1996	- To regulate that all power projects to follow the Environmental Impact Assessment (EIA) procedures.	[27]
	Power Sector Strategy 1999–2016	- To provide sufficient electricity throughout Cambodia and to investors at a reasonable tariff. - To encourage efficient use of energy and environmental-friendly development of energy.	
	Rural Electrification by Renewable Energy Policy 2006	- To create an enabling framework for renewable energy technologies to increase access to electricity in total areas.	
	Renewable Electricity Action Plan (REAP) 2002–2012	- To provide cost-effective and reliable electrification of rural Cambodia through renewable energy technologies.	
Indonesia	The Geothermal Law 2003	- To empower the regional government in geothermal energy developing.	[27]
	The Green Energy Policy 2004	- Guidelines for the development of renewable energy.	
	Energy Law 2007	- Focused on utilization of the energy resource, energy conservation and environmental protection.	
	The Electricity Law 2009	- To promote energy conservation, secure sustainable energy supply and use of renewable energy.	
	Biofuels subsidy 2009	- To encourage the investment and the use of biofuels.	
Laos	Power Sector Policy	- To increase the household electrification ratio and to increase use of indigenous energy resources.	[27]
Malaysia	National Energy Policy	- To promise the sufficient, safe, cost effective and diverse sources of energy supplies. - To promote the efficient utilization of energy and environmental protection are considered in the production and use of energy.	[27]
	Five-Fuel Policy 2002	- To reduce the dependence on oil as energy source by optimizing the fuel mix with oil, gas, hydro-electric and coal and renewable energy.	
	Efficient Management of Electrical Energy Regulations 2008	- To implement efficient electrical energy management.	
	National Green Technology Policy 2009	- To promote the development of green technology activities towards sustainable development in energy, environment, economy and society.	
	Malaysian National Renewable Energy Policy and Action Plan 2010	- To enhance the utilization of indigenous renewable energy sources to contribute towards national electricity supply security and sustainable socio-economic development.	[28]
	Renewable Energy Act 2011	- To provide the establishment and implementation of a special tariff system to catalyze the generation of the renewable energy and to provide for the related matters.	[29]
	Sustainable Energy Development Authority Act 2011	- To provide the establishment of the Sustainable Energy Development Authority of Malaysia and to provide for its functions and powers and for related matters.	[30]
Myanmar	Myanmar Electricity Law 1984	- To supervise electric power generation, transmission; distribution and utilization for the general safety of public.	[27]
	Energy Policy of Myanmar	- To maintain the energy independence status and to promote energy efficiency and conservation. - To encourage the use of new and renewable energy source and alternative fuels.	[31]
Philippines	Mini-hydroelectric Power Incentive Act 2001	- Incentives are given for mini-hydro projects.	[22,27]
	Biofuels Law 2006	- To reduce dependence on imported oil; protect the environment and ecosystem; and increase rural employment and income.	
	Renewable Energy Act 2008	- To promote the development of renewable energy by incentive rewards to the private sector.	
Singapore	Energy Policy	- To maintain economy competitiveness, energy security and environmental sustainability in balance.	[27]
Thailand	Thailand's Energy Policy 2006	- To promote sustainable energy development and sufficient energy supply. - To promote energy conservation and energy efficiency.	[32]
	Energy Industry Act B.E. 2550 (2007)	- To promote economical and efficient use of energy with consideration of environmental impact. - To promote the use of renewable energy.	[33]
Vietnam	The Electricity Law 2005	- To stimulate development and diversity forms of investments in electricity sector towards a competitive electricity market. - To encourage the economical use of electricity and maintain the nation's electricity infrastructure.	[34]

Table 3
Renewable energies developed in Southeast Asia's countries with their research programs and installed projects.

Country	Renewable energy	Installed projects	Ref.
Brunei	Solar	• Solar diesel hybrid electric power system at Ulu Belalong National Park, Temburong (2000) • Tenaga Suria Brunei (TSB)—1.2 MW[a] photovoltaic (PV) power generation demonstration project (2010)	[35]
	Wind	• 1st wind turbine at Ministry of Development—for energy potential study	
Cambodia	Solar	• Demonstration systems on health and rehabilitation centers by international organizations such as UNICEF, Red Cross, SIDA and FONDEM • Solar system for low income households in rural areas by Solar Home Systems (SHS)	[35,36]
	Wind	• Pilot projects financed by the government of Belgium and the European Commission	
	Biomass	• Scale demonstration cogeneration plant using r ice husk—1.5 MW	
Indonesia	Solar	• Hybrid solar PV systems for rural household and street lighting • Installation of solar home systems (SHS) is in a semi-commercial stage	[35,37]
	Wind	• Current installed capacity is 500 kW[b], primarily used for water-pumping and the charging of batteries	
	Hydro	• Current installed capacity is 2550 MW	
	Biomass	• Current installed capacity is 445 MW	
Laos	Solar	• PV solar technology is used for water pumps, water purification, and communications • Current installed capacity is 285 kW	[35]
	Hydro	• Nam Theun 2 Project with capacity 1088 MW was completed by 2009 • Memorandums of Understanding have been signed for more than 70 projects	
Malaysia	Solar	• 100 kWp Demonstration PV Project—Ministry of Energy, Water and Communication 1995	[38,39]
	Wind	• 150 kW wind turbine in the Terumbu Layang Layang (2005) • 2 Units 100 kW wind turbine in Pulau Perhentian by TNB • 8 Units of small wind turbines (5–10 kw) in Sabah & Sarawak for community by Ministry of Rural and Regional Development	
	Hydro	• 12 large-scale and 50 small scale power stations by 2009 • Total installed capacity is 18,500 MW	[40]
	Biomass	• Pasir Gudang, Johor—630 kton/year • Lahad Datu, Sabah—300 kton/year • Kuantan, Pahang—200 kton/year • Ipoh, Perak—200 kton/year • Teluk Panglima Garang, Selangor—150 kton/year • Setiawan, Perak—60 kton/year	
Philippines	Solar	• Installed capacity is 567 kW by 2000	[35]
	Wind	• 25 kW stand-alone system with six different loads in Batangas • 3 kW wind-diesel system for telecommunications relay station • 25 MW wind farm in Bangui Bay, Ilocos Norte	
	Hydro	• Generates 3367 MWh from hydro source	
	Biomass	• 6 MW biomass combustor plant using rice husk in Panay Island • Current installed capacity is 920 MW mainly using sugar, rice husk and coconut	
	Geothermal	• Installed capacity is 1930 MW by 2003, supplying 9400 GWh[c] of electricity	
Singapore	Solar	• Changi's Airport Budget Terminal PV power plant—250 kWp[d] • Resorts World Sentosa—503.37 kWp • SingTel (telephone exchange with PV system), Pasir R is—39.98 kWp • Zero Energy House, Singlap—8.58 kWp	[41,42]
Thailand	Solar	• 1 MW solar PV program for grid connected system generating 1600 MW h per year • Thailand's first commercial solar cell manufacturing facility by the World Bank—20 MW	[35,37]
	Wind	• 7 Wind turbines were installed with total capacity 192.4 kWe	

Table 3 (*continued*)

	Hydro	• 50 MWh of hydropower generation was installed by 2007	
	Biomass	• Biogas systems generated 29.2 MWh power (2007) • Cogeneration system with rice husks	
	Geothermal	• 300 kW binary-cycle geothermal plant in Fang District geyser field, Chiangmai	
Vietnam	Solar	• About 5000 solar photovoltaic systems generating 650 kW electricity	[35]
	Wind	• Wind Power Plant No. 1, Binh Thuan (First wind turbine plant project in Southeast Asia) • Pilot wind power project, Ninh Thuan—30 MW	
	Hydro	• Son La project—2400 MW by 2012. • 480 small hydro-plants at northern and southern area with total 2887 MW generation	
	Biomass	• 750 kW waste-to-power project (Funded by the US and Netherlands)	

[a] Megawatt.
[b] Kilowatt.
[c] Gigawatt hour.
[d] Kilowatt peak.

viewed to have a bright future in Southeast Asia. Inspired by the legislations and policies, the potential of renewable energy, such as solar, wind, hydro, biomass, and geothermal, in this region have been unearthed. Table 3 presents the some of the existing renewable energy projects in Southeast Asia. Some of these projects were funded by developed countries. A pleasant output from Renewable Energy Act 2008 was seen in Philippines when renewable energy contributed 33% of the nation's energy mix in 2010 [22]. Malaysia achieved only 20% of its renewable energy target in its 9th Malaysia Plan by 2010 [23].

In short, all the countries are aware of the importance and their duties in global warming mitigation. At this stage, there is still no obvious achievement seen. More efforts have to be given and it will be a long-term goal to achieve for these countries.

3.1.2. Transportation sector

Tremendous CO_2 emission growth in Southeast Asia is one of the consequence of rapid population and economic growth which brings about dense transport energy intensity [24]. In transportation sector, focus is always on reducing the over-dependence on petrol due to the unstable market price and limited reservoirs of petroleum. Thus, CO_2 emission from transportation is also taking some credits from these matters.

In order to mitigate CO_2 emission, four major approaches have been taken i.e. alternative vehicles, alternative fuels, fuel efficiency improvement, and intelligent transport system [25]. The approaches have been realized through regulatory, fiscal, policy and investment.

It was noted that there is no specific regulation in Southeast Asia countries to control the CO_2 release from transportation. However, in Singapore, due to limitation of land area, they have implemented large-scale land transportation measurements. Singapore has developed a Vehicles Quota System (VQS) to suppress the growth of the country's vehicles [43]. The nation's vehicles annual growth which is set at 1.5% [44]. This measurement indirectly lowers the CO_2 emission from transportation in Singapore.

Thailand had attempted to promote the production of eco-cars by giving tax exemption to the industry in 2007 [24]. In Philippines, National Environmentally Sustainable Transport (EST) Strategy and Action Plan was launched under the monitoring of Department of Transportation and Communication (DOTC) and Department of Environment and Natural Resources (DENR). The framework includes the transport, freight and logistics planning, aiming to curtail the growth of energy consumption and greenhouse gases emission [45]. Task Group Fossil Fuel (TGFF) is another program in Philippines that encourages non-motorized transportation system in the country in order to reduce the fuel consumption [46]. This bolsters the reduction of transportation CO_2 reduction at the same time. Malaysia recorded a drastically increase in its number of NGV vehicles in 2008 when fuel subsidies were gradually removed due to government policy [47].

Despite of reducing CO_2 emission from vehicles, Southeast Asia countries has other pressing concerns in their transportation system, such as market fuel price, overcrowding of the vehicles, and land limitation. All the policies and legislations mentioned above are more to overcome the pressing issues of these countries, but they indirectly encourage CO_2 reduction in the same time.

3.1.3. Commercial and residential sector

Although industrial, commercial and residential sectors are not the top contributor in CO_2 emission, some of the Southeast Asia governments have also targeted to reduce the CO_2 emission from these sectors. In Vietnam, the “green building” action, which focuses on the fuel switching and natural energy utilization, is one of the measures to reduce the CO_2 emission from commercial and residential sectors. It is expected to eliminate 39% and 48% CO_2 reduction in commercial and residential sectors, respectively [48]. Besides than efficiency improvement in household by replacement of efficient electric devices, Thailand has also fixed their building code to be followed. The building codes are expected to improve the energy efficiency by 20% [49]. Minimum energy efficiency standards for room air conditioners have been fixed by Malaysia Energy Commission in early 2004. The measure has been proven beneficial for the environment, consumers and governments in the analysis [50].

3.2. Regional and international efforts

3.2.1. Role of ASEAN

Since 2000s, the awareness of the critical environmental issues especially on global warming is blooming among Southeast Asia countries. The countries involved, started to participate proactively and more specifically in environmental issues, including global warming. Protection of the environment is always one of the

Table 4
Declarations/statements made on global warming issues by ASEAN on regional meetings [55,58,80].

Declarations/Statements	Meetings/Events
ASEAN Declaration on Environmental Sustainability	13th ASEAN Summit, 2007
ASEAN Declaration on COP-13 to the UNFCCC and CMP-3 to the Kyoto Protocol	13th ASEAN Summit, 2007
Singapore Declaration on Climate Change, Energy and the Environment	3rd EAS Summit, 2007
Joint Ministerial Statement	1st EAS Energy Ministers Meeting, 2007
Ministerial Statement	Inaugural EAS Environment Ministers Meeting, 2008
Joint Media Statement of the Special ASEAN Ministerial Meeting on Climate Change	Special ASEAN Ministerial Meeting on Climate Change, 2009
ASEAN Joint Statement on Climate Change to COP-15 to the UNFCCC and CMP-5 to the Kyoto Protocol	15th ASEAN Summit, 2009
ASEAN Leaders' Statement on Joint Response to Climate Change	16th ASEAN Summit, 2010
ASEAN Leaders' Statement on Climate Change to the COP-17 to the UNFCCC and CMP-7 to the Kyoto Protocol	19th ASEAN Summit, 2011

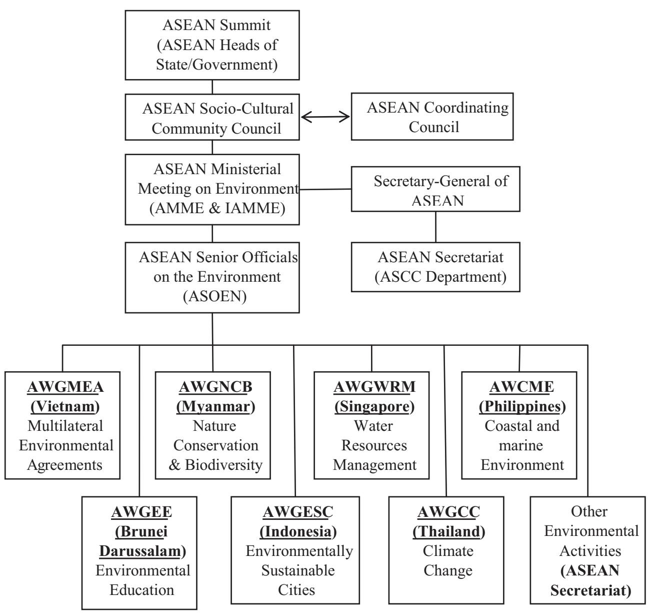


Fig. 3. Current ASEAN Institutional Framework for Environmental Cooperation [56].

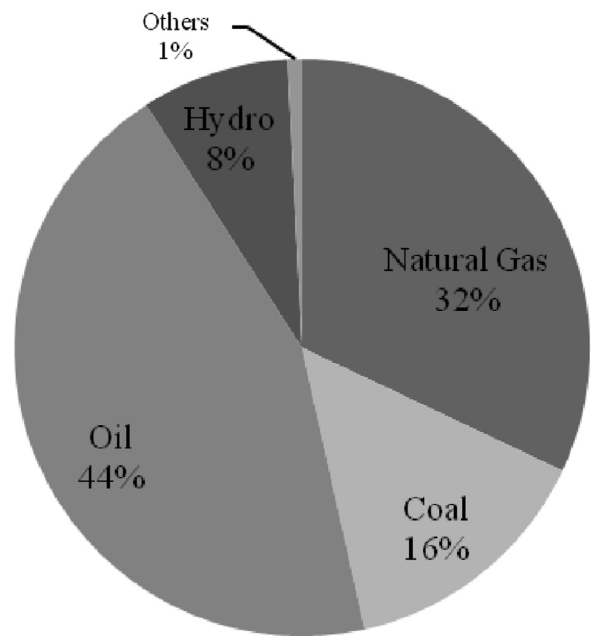


Fig. 4. Energy mix estimation in ASEAN region by 2010 [79].

major topics discussed at the ASEAN meeting, trying to address the issue through implementation of a variety of measurements [51–52]. Blueprint for ASEAN Socio-Cultural (ASCC Blueprint 2009–2015) has called for cooperation in global warming adaption and alleviation with the principles of equity, flexibility, and effectiveness [53]. The efforts done including declarations, institutional framework establishment, and collaboration with developed countries.

Environmental issue is one of the hot topics to be discussed at the ASEAN Summit. The member countries leaders adopted ASEAN declaration or statement on climate change corresponding to the conference of the parties (COP) to the United Nations Framework Convention on Climate Change (UNFCCC) and the conference of the parties serving as the meeting of parties to Kyoto Protocol (CMP). The declaration was being renewed timely according to the commitments achieved in COP and CMP at the moment. The latest ASEAN Leaders' Statement on Climate Change was made during 19th ASEAN Summit held in Bali, Indonesia, November 2011 [54]. The statement has highlighted the importance of climate change issue, worked as a guideline for the ASEAN members in achieving objectives under COP17 and CMP7, and enable the member countries work as a unity to mitigate the problem [55]. Table 4 shows some of the declarations made by ASEAN related to climate change at different levels of meetings.

Aside from the declarations/statements made, institutions were formed under ASEAN. The current ASEAN institutional framework for environmental cooperation is presented in Fig. 3. The framework's working direction is guided by the importance reflected in ASCC Blueprint 2009–2015 [56]. ASEAN Senior Officials on the Environment (ASOEN) is the main institution that directly responsible for the environmental issue, including climate change. It was elevated from ASEAN Expert Group on the Environment (AEGE) in 1989 [57]. The working groups under ASOEN, as listed in Fig. 4, will make the policy guidance on difference environmental programs. ASOEN's responsibilities are in the scope of formulation, implementation and monitoring the regional programs and activities along with the ASEAN Ministerial Meeting on the Environment (AMME)'s outcomes. ASEAN Environment Ministers have their formal meeting, ASEAN Ministerial Meeting on the Environment (AMME) is the formal meeting of ASEAN Environment Ministers every 3 years since 1981 [58]. The meeting aims to monitor the implementation of the Heads of Government's decisions regarding to environment and to promote closer cooperation among ASEAN countries [57].

In addition to cooperation among the member countries, ASEAN is also having external cooperation with countries worldwide in various fields, including environmental issue. ASEAN Plus Three (APT) is a cooperation formed between ASEAN and three East Asia countries, namely China, Japan, and South Korea. The cooperation has started in 1997 and has broadened and deepened throughout these years. Besides than APT cooperation, ASEAN is having external relations with European Union, India, Pakistan,

Table 5
External cooperation of ASEAN in environmental issues [81].

External relations	Details
ASEAN Plus Three (APT)	**APT Environment Ministers' Meeting (ASEAN+3 EMM)** To address the issue of environment and sustainable development **APT Leadership Program on Sustainable Production and Consumption (17–19 Oct 2012 in Manila)** A program for private sector to discuss green economy **ASEAN+3 Youth Environment** To promote and exchange environmental ideas among the region youths
South Korea	**East Asia Climate Partnership** Allocated US$100 million to support ASEAN member s countries in the area **Asian Forest Cooperation Organization (AFoCO)** A flagship project related to South Korea's "Low-Carbon Green Growth" initiative
Japan	**13th ASEAN-Japan Summit 2011** welcomed all the efforts to address climate change issues
China	**China-ASEAN Environmental Cooperation Center (CAEC)** A center for environmental cooperation between ASEAN and China **ASEAN-China Environment Cooperation Action Plan** To establish ASEAN-China environmental cooperation mechanism, including ASEAN-China Ministerial Meeting& ASEAN-China Environmental Cooperation Forum To promote the cooperation on environment industry To implement the ASEAN-China Green Envoys Program To promote joint research
European Union (EU)	**The Regional EU-ASEAN Dialog Instrument (READI)** A policy dialog mechanism/process for promoting the ASEAN-EU dialog relations in non-trade areas **Nuremberg Declaration on an EU-ASEAN Enhanced Partnership 2007** To strengthen cooperation between EU and ASEAN in climate change, in particular reducing greenhouse gas emissions and improving air quality To undertake concrete action for the implementation of UNFCCC and Kyoto Protocol
India	**ASEAN-India Green Fund** To support cooperative pilot projects with technologies that promoting climate change adaption and mitigation

and Canada in environmental issue. Some of details of the cooperation are reported in Table 5.

In short, ASEAN is the core of the Southeast Asia countries to activate the region action plan in global warming mitigation. It decides the policies and declarations which become the guidelines in the member countries' development. It consolidates all the countries power and strength for tight internal region cooperation as well as fosters more effective external relations with foreign countries.

3.2.2. *Carbon development mechanism (CDM)*

Carbon Development Mechanism (CDM) is one of the policy introduced by UNFCCC under Kyoto Protocol 1997, giving flexibility in CO_2 reduction to the Annex-I countries (industrialized countries and countries with economies in transition) while benefiting the non-Annex-I countries (developing countries, including Southeast Asia countries) towards a sustainable development. CDM created a global trade market for CO_2 reduction. Annex-I countries, with CO_2 reduction commitments, are allowed to invest in carbon reduction projects in non-Annex I countries as part of their reduction [59]. These projects members will be given carbon credits, called 'certified emission reductions' (CERs). These CERs can be traded as part of the countries' CO_2 reduction. As non-Annex I countries,

Table 6
Total approved CDM projects and CERs issued in Southeast Asia countries until 2010 [63].

Countries	Registered CDM Projects	CERs issued
Malaysia	93	799,858
Indonesia	66	1,349,887
Philippines	52	240,036
Thailand	49	851,541
Vietnam	56	6,646,339
Cambodia	4	10,758
Laos	1	2168
Singapore	2	–
Total	323	9,900,587

Southeast Asia countries can utilize CDM as a tool to obtain more investment from private sector in CO_2 reduction. Total approved CDM projects in Southeast Asia countries until 2010 are shown in Table 6. By 2010, the number of CDM projects in Southeast Asia region hits 323 projects, which is around 10% of total CDM projects. Most of the projects are concentrating on energy sector, where conventional fossil fuel power source is tried to be substituted by renewable energies [60].

Conceptually, CDM is a benign policy designed for benefiting both developed and developing countries. It helps to catalyze low carbon sustainable development in developing countries efficiently [61]. CDM also provides a platform for the knowledge and technologies transfer [62].

4. Barriers in CO_2 reduction efforts

Despite uncountable efforts in reducing CO_2 have been done, they have been denied by the drastic increasing trend of CO_2 emission. Hence, to overcome this problem, the barriers have to be recognized and studied; in order the effort will bring fruitful attempts.

4.1. *Deficiencies of the implementation*

As reported previously, appropriate efforts have been carried out by the parties involved under the name of global warming mitigation. However, consensus is always hard to be reached in this issue. From the workshops, meetings, or conferences held, we can hardly see a plausible outcome from them. This circumstance is not only happen in Southeast Asia but the whole world. For instance, Copenhagen Accord, which was considered as the continuation of Kyoto Protocol, came out as a weakly-bound cooperation, which its implication is unclear [63]. The world, including Southeast Asia, is still looking forward for a more valid agreement to lead for the worldwide climate change mitigation. In addition, the outcomes of the events or activities have to be monitored and reviewed periodically. Improvements and amendments have to be done in the view of ineffectiveness of the program. Besides that, most of the events or activities launched were not thoroughly enough. They involved only the leaders and the experts and rarely reach the public. Public awareness can help residential energy saving, and also 'supervise' the progress of the programs implementation. The parties involved will envisage into the issue when it become the main concern of the public.

4.2. *Divergence in countries' policies*

Southeast Asia countries have big divergence in their economy status and countries' policies. Singapore and Brunei are classified as wealthy nation among ASEAN countries. Malaysia, Thailand, Indonesia,

Philippines and Vietnam are developing countries while Laos, Cambodia and Myanmar are still far lagging behind other countries. Singapore and Brunei, anyway, face difficulties in handling this issue due to their limited natural resources and heavy dependences on fossil fuel. Meanwhile, countries such as Myanmar, Cambodia, Laos, and Vietnam, are poor and unstable to combat the phenomenon. Besides that, big variation in the economy status has aggravated the region cooperation in global warming issue. Many programs and projects are not viable due to this great disparity. Aside from that, these countries also have different ruling system. Most of the countries are implementing constitutional monarchy or democratic system; Brunei is still practicing absolute monarchy system where all the power is controlled by the King or Sultan. Owning abundant petroleum resource, oil and gas make up major revenue of Brunei [64]. Thus, the nation is showing less interest towards CO_2 reduction. Cambodia was practicing close-door diplomatic previously [65]. Due to the policy, investors have least interest towards the country and therefore, technology and fund transfer was low. Therefore country such as Cambodia had tighter regional cooperation among other countries. To date, ASEAN countries still have rooms to explore and in order to achieve borderless cooperation in environmental issue.

4.3. Restrictions of renewable energy technologies penetration

Blessed with abundant natural resources, Southeast Asia countries are potential candidates for renewable energy promotion. Unfortunately, the introduction of renewable energy is still at a very preliminary stage and underutilized. Fig. 4 indicates the estimation of energy mix sources in Southeast Asia countries in 2010. It clearly shows that coal, natural gas and oil products remain as the significant energy sources while renewable energies and other energy sources are yet to replace them. Referring to Table 3, many renewable energy projects installed in this region are small scale or pilot research scale.

In natural, renewable energy sources, especially wind and solar, are inherently stochastic [66]. To overcome this limitation, many power systems have been built in hybrid form, where the renewable energy source is combined with diesel generator, to ensure the continuity of the power supply. Meanwhile, renewable energy source like hydropower needs large spacing and has potential to destroy the natural habitat [67]. A proper area assessment needs to be carried out before the hydropower project is being launched. The impacts must be closely monitored from time to time.

Besides that, lack of experience and knowledge has made the energy transformation a tough task to Southeast Asia. In addition, exploitation of new energy sources has been identified as a risky investment and not economically viable for the investors. Besides, limited funding has worsened the development of renewable energy to substitute the conventional energy sources.

4.4. Deficiency of clean development mechanism (CDM)

CDM, which aims to benefits both developed and developing countries in term of addressing global warming issue and sustainable development [60], has faced some barriers in its implementation, whereby the objectives could not be interpreted clearly. Since inception of the CDM, its ability in achieving the dual objectives have been questioned by many parties [68]. Sustainability of CDM projects is only examined in assessment of 15 countries [69]. Dr. Adam Bumpus, in his article published by UNFCCC Secretariat [61], explained that this is because the difficulty in term of sustainable development measurement, a CDM project may be benefited more than what are claimed. In addition, the distribution of the CDM projects was found to be uneven. They concentrated in the larger developing countries, whilst some smaller least developed countries are neglected [62]. From the statistic revealed by UNFCCC in 2010, it shows that the distribution of CDM projects is absolutely uneven, where most of the projects are grabbed by China (44.9%) and India (21.2%) [70]. It reflects that not every non-Annex I countries are benefited from CDM projects, including Southeast Asia Countries. Countries like Brunei Darussalam and Myanmar are not entitled to CDM due to the countries' policy. Brunei is affix to neither United Nations Framework Convention on Climate Change (UNFCCC) nor Kyoto Protocol while Myanmar was practicing closed-door diplomatic policy previously [65]. Without subsidies or revenues from CERs sale, many CDM projects are not viable. For instance, Roi-Et Green Power Plant in Thailand obtained subsidy from Energy Policy and Planning Office (EPPO) and the Global Environment Facility (GEF) while Energy Conservation Promotion Fund gave subsidies to PRG Granary Co., Ltd [71].

4.5. Lack of interest

To date, it is sad to note that addressing the issue of climate change is still not the main concern in both industrialized and developing countries. In developing countries like Southeast Asia, there are always more pressing and knotty concerns, such as livelihood issues and economic transformation. Although efforts are also given into climate change mitigation, it will never come to the priority when it is conflict with the economic growth. Same circumstance happens in the CDM, where the host countries (developed countries) are seeking for the project profit, while the developing countries' focus is on the development brought by the CDM project. Mitigating global warming, which is one of the main objectives under this mechanism is always being put behind.

5. Future recommendations

Southeast Asia is one of the most vulnerable regions to the climate change threat. It is sometimes unaffordable for these countries to against the problem even if they intended to. At the moment, financial aid and technology transfer are the most helpful measures in addressing the issue. CDM is one of the applausive approaches in this purpose although it still finds some barriers in its implementation. Southeast Asia is in an unfavorable situation compared to other large developing countries, such as China, India, and Brazil, in getting CDM projects. However, according to CDM Annual Report 2010 [72], the CDM executive board has looked into feedbacks from all parties and modifications have been made to ascertain more equitable participation and friendly procedure for both Annex-I and non-Annex-I countries. For instance, a new load scheme has been launched for countries with less CDM projects so that the projects can be distributed more evenly. New application procedures with clear timelines have also been designed in order to make the mechanism runs more efficiently.

Besides the CDM, regional association, ASEAN, has an imperative role to play. It has to bring all its member countries to a round table periodically, heading towards borderless regional cooperation in environmental issues. It needs to act more proactively and efficiently in expressing the region's standpoint and barriers at the international level, seeking for the effective solution in addressing global warming issue. While looking for more cooperation with other countries, existing cooperation with other regional countries, such as Japan, China, and Korea, should be broadened and deepened. In particular, reviews on the programs or events launched have to be done periodically to ensure that the preset objectives and targets are achieved. Efforts done have to focus on the root of the problems rather than making furnishing reports at international, regional, and governmental level.

Nevertheless, this is not the ultimate solution for long run. The region has to come out with its own independent solution, on

the par with countries such as European Union, Japan, and Korea. The region needs a more satisfactory legislation system in order to give more effective control towards CO_2 emission from power generation sector. European Union has set a paradigm with The EU Emission Trading Scheme [73]. In 2010, ExxonMobil in United Kingdom has been fined £2.8 million over its failure in accounts 33,000 t CO_2 emitted in their report year 2008 [74]. In transportation sector, it is a must to implement fuel economy standard in order to achieve CO_2 reduction. It is a minimum requirement of energy performance that must be met by motor vehicles [47]. Of course, due to the difference in the economic and politic, the stringency and scope of the implementation has to be studied and deployed to suit the country's condition.

With the inheritance of abundant natural resources, Southeast Asia countries have a very good potential in renewable energy development. Many researchers have studied for the potential of implementation of renewable energy system in this area. For instance, a techno-economic feasibility study of a hybrid PV/diesel/battery/power system has been carried out by Lau et al. [75], said that the system manage to reduce the dependence of diesel in the country as well as reduce the CO_2 emission. Countries such as Brazil should become their target of emulation. Brazil, a developing country that renowned with biofuel production, is the 5th largest country in the world in renewable energy consumption. In 2003, the sales of flexible fuel vehicles (FFVs), which able to consume a mixture bioethanol and gasoline compromised more than 70% of total new cars sold in Brazil [76]. More government supports and experiences sharing need to be put in order to make renewable energy power sources a replacement to fossil fuel in the region.

6. Conclusion

This paper has generally described and reported efforts taken on global warming mitigation in Southeast Asia countries. These developing countries are categorized under non-Annex-I countries, have neither mandatory nor voluntary commitments to reduce CO_2 emissions under the Kyoto Protocol. However, encouraging responses have been shown by these countries. Southeast Asia is not the main CO_2 emitter, but its exponential increasing trend will bring tremendous impacts in the coming years if it is being ignored. Energy, transportation and deforestation are the three main sectors that have contributed to CO_2 emission in the region. Governments have their policies towards this threatening issue, but there is neither a regulation nor a penalty towards the excessive CO_2 emission anyway. ASEAN represent these countries' voice at international level and has played its roles proactively. Countries like Thailand, Malaysia, Indonesia and Philippines are benefiting from CDM. However, efforts done so far seem deficient as the CO_2 emission increases drastically annually. Southeast Asia countries are still lagging behind in their technology development. In addition, environmental strategies achieve very little unless it is tied to socio-economic and trade or international obligations. These factors have made the efforts unable to achieve their expected result. Technology and fund transfer from developed countries is vital as an aid to these vulnerable countries while criticism will make no influence. Aside from that, in order to create a sustainable development along with global warming mitigation, more frequent internal cooperation among ASEAN countries is needed.

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